The Design of a Four-Year ASCE BOK Compliant Program Tract

Michael Robinson, P.E., Kevin Sutterer, P.E.
Department of Civil Engineering
Rose-Hulman Institute of Technology

Introduction

The American Society of Civil Engineers (ASCE) Task Committee on Academic Prerequisites for Professional Practice ($TCAP^3$) developed a body of knowledge (BOK) that defines the knowledge, skills and attitudes (termed outcomes in the BOK) and their associated level of competency considered necessary to practice as a licensed professional civil engineer.[1] The BOK is to be achieved through both formal education and work experience with formal education occurring both at the baccalaureate and post-baccalaureate level. However, the BOK does not explicitly divide formal education into baccalaureate and post-baccalaureate levels. Therefore, each civil engineering program will determine what part of formal education can be achieved in their baccalaureate program and what part should be met in a post- baccalaureate program. Based on an earlier analysis of the civil engineering program at Rose-Hulman Institute of Technology we have concluded that outcome 12 of the BOK, an ability to apply knowledge in a specialized area related to civil engineering, was not attainable within our current four-year baccalaureate program. In addition, we concluded that modification of the curriculum to meet the complete formal education component was not in the best interest of either the department or our students. Therefore, outcome 12 would need to be attained in a post-baccalaureate program.[2]

Many students enter their first-year at Rose-Hulman Institute of Technology with credit hours earned through advanced placement, college transfer credit, or Rose-Hulman's summer Fast-Track Calculus program. In addition, students are encouraged by faculty to take a humanities course during summer breaks to earn transfer credit. These credit hours are termed "off-curriculum" in that they are earned outside our curriculum. Students with off-curriculum credit hours frequently earn non-engineering related minors, reduce their course-load, or take courses of interest not related to an academic degree program. Many civil engineering students graduate with credit hours in excess of the current requirement of 194 quarter hours. For example, for the three civil engineering classes graduating between 2001 and 2003 the median number of credit hours at graduation was 200 with five students graduating with 230 or more credit hours. We expect to see both the number of students earning off-curriculum hours and the number of off-curriculum credit hours earned to increase.

We wanted to determine if we could find a mechanism for students to earn the formal education component of the BOK at Rose-Hulman. Our solution was to investigate the development of a tract within our current four-year baccalaureate curriculum that would allow a student with a high number of off-curriculum hours to earn a four-year baccalaureate degree that satisfies the entire formal education component of the BOK. The current curriculum at Rose-Hulman satisfies 14 of the 15 BOK outcomes. The new BOK compliant tract must specifically meet outcome 12, an ability to apply knowledge in a specialized area related to civil engineering. To maintain the broad civil engineering education and project-based design philosophy that are hallmarks of the civil engineering program at Rose-Hulman there were to be no changes to the current curriculum to accommodate the development of the BOK compliant tract. To maintain the integrity of the civil engineering program, all engineering courses within the current curriculum must be taken at Rose-Hulman. Additional courses included in the BOK compliant tract to achieve specialization may not necessarily be limited to courses offered at Rose-Hulman. Our intent is not to modify the current curriculum but to offer an alternate tract within the current curriculum that would allow for students with sufficient off-curriculum hours to take the additional courses required for specialization. In addition, we prefer to limit any increase in faculty teaching loads.

Current Four-Year Curriculum

Rose-Hulman is a four-year, private, non-sectarian college of engineering, science, and mathematics located in Terre Haute, Indiana. Undergraduate enrollment for the 2004/05 academic year is 1,765. The most recent freshman class of 473 students had a median SAT of 1,300 with 92 percent graduating in the top 20 percent of their high school class. The Civil Engineering Department is an undergraduate focused engineering program with an enrollment of approximately 120 students and six faculty. The Department offers a minor in environmental engineering and a Masters of Science in environmental engineering. The graduate program has a current enrollment of two students.

The civil engineering curriculum contains 55 courses totaling 194 quarter-hours. The number of courses and credit hours per content area is shown in Table 1. The academic year is divided into three ten-week quarters in which a typical civil engineering course load is between 14 and 18 hours per quarter.

Table 1. Content areas within the civil engineering curriculum by courses and credit hours.

Content Area	Number of Courses	Credit Hours	Percent of Total Hours
Humanities / Social Sciences	9	36	18.6
Mathematics	6	27	13.9
Science	6	24	12.4
Engineering Mechanics / Science	6	24	12.4
Civil Engineering	28	83	42.7
Total	55	194	100.0

A flowchart showing the sequencing of courses and credit hours per quarter of the current curriculum is shown in Figure 1. Faculty resources limit most civil engineering courses to a single offering per year and prerequisites are generally strictly enforced. This often limits students from taking required courses earlier than their scheduled offering. For example, consider a student wanting to take CE321 Structural Mechanics I earlier than the fall quarter of their junior year. Only offered only in the fall quarter, CE321 has a prerequisite of EM203 Mechanics of Materials. Offered only in the winter quarter, EM203 would then be taken in the winter quarter of the freshman year. However, EM203 has a prerequisite of EM120 Engineering Statics, which would need to be taken fall quarter of freshman year. EM203 could not be taken in the fall quarter due to its MA111 Calculus I prerequisite. Students are required to take nine humanities / social sciences (HSS) courses from four different thematic categories: rhetoric and expression, global studies, self and society, and values and contemporary issues.

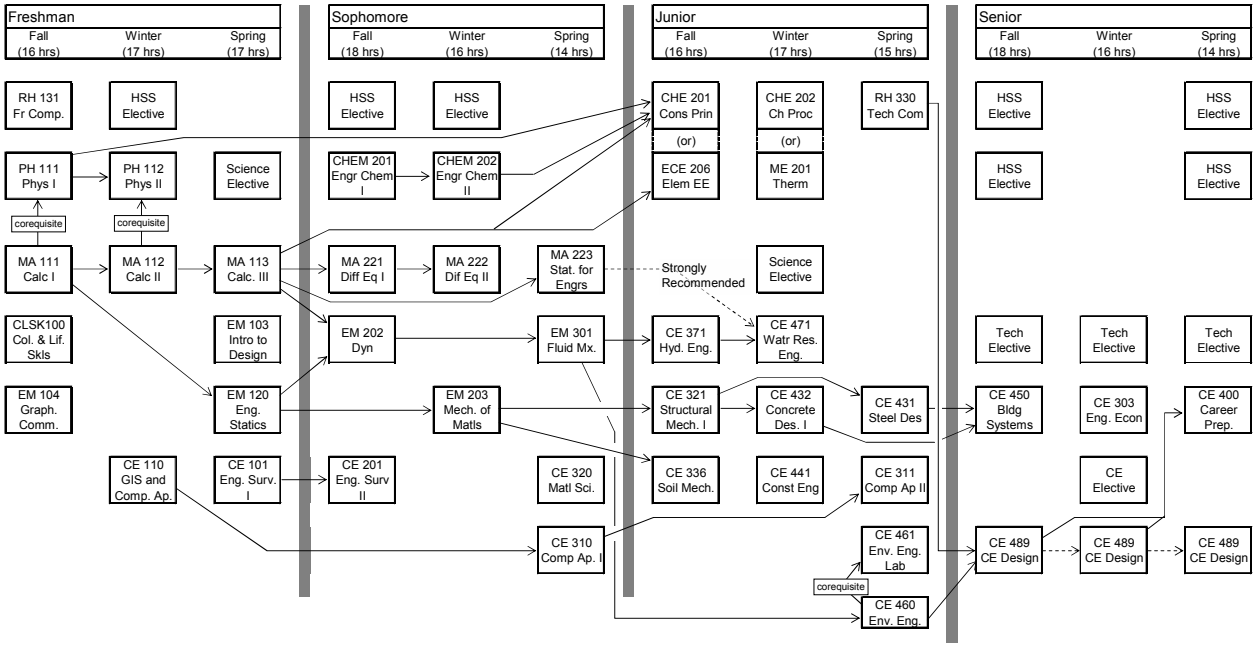

Figure 1. Course flowchart for current civil engineering curriculum. Arrows represent course prerequisites.

Creating the BOK Compliant Tract

A student must have sufficient off-curriculum credit hours to allow for additional courses to be placed into their curriculum to meet the specialization outcome. The BOK does not specify the number of courses or credit hours needed to achieve the formal education component. However, the following statements are in the BOK: "additional education beyond the bachelor's level might be flexibly interpreted Outcome 12" and that "the BOK would be fulfilled via the Bachelor's Plus Master's or approximately 30 credits & experience." We interpret that

specialization requires 30 credits or 10 courses. Space within the four-year curriculum was needed to add these ten additional courses. It is not possible to add ten additional courses into the curriculum and graduate a student within four years. Therefore, courses had to be removed from the curriculum through credit received for off-curriculum credit hours. Two curriculum content areas were considered for off-curriculum credit: mathematics and HSS.

One option available in the mathematics area is Rose-Hulman's Fast-Track Calculus program. The program is available on a competitive basis to academically outstanding freshman who have one year of calculus and analytic geometry in high school. Fast-Track Calculus is an intensive five-week course offered during the summer prior to the freshman year. Successful completion of the program earns the student 15 credit hours for the freshman calculus sequence (Math 111, Math 112, and Math 113). A longitudinal study conducted for the Math Department indicated that participation in the Fast-Track Calculus program does not adversely affect a student's academic performance as measured in terms of mean grade point average.

Humanities and social sciences courses are an important component of the Rose-Hulman education. They constitute the largest content area other than civil engineering courses in the civil engineering curriculum, see Table 1. Students are required to take nine courses from four thematic areas. Students often earn an area minor from one of the 16 area minors the HSS Department offers. HSS courses are an integral but not integrated component of the civil engineering curriculum. It is not uncommon for students to receive transfer credit for four or five HSS courses and we encourage our students to take HSS courses during summer breaks at nearby institutions. Therefore, we do not feel that students transferring credit for HSS courses lowers the quality of the education they receive at Rose-Hulman.

A course flowchart of a BOK compliant tract, Figure 2, was developed to indicate where in the curriculum specialization courses could be taken. Math 111, Math 112, Math 113, and five HSS courses were replaced with eight courses to meet the specialization outcome. Two new courses were added to the tract to achieve the required 10 courses. No specific courses for the specialization outcome appear within the flowchart only placeholders for the courses. The 15 credit hours of mathematics (Math 111, Math 112, and Math 113) and the 20 credit hours of HSS are still required but are either earned through the Fast-Track Calculus program, A.P. credit, or transfer credit. The BOK compliant tract has 57 courses totaling 199 credit hours. This compares to the 55 courses totaling 194 quarter-hours in the current curriculum. No civil engineering courses were moved from their standard sequence within the curriculum.

Courses to meet the specialization outcome were placed either in the junior or senior year of the curriculum with the exception one course. Several courses were moved earlier within the curriculum to allow for specialization courses to be taken later in the curriculum, Table 2. We wanted to maximize the specialization courses within the junior and senior years without exceeding course load limits. The maximum course load permitted at Rose-Hulman is 18 credit hours. A student's academic advisor can approve six credits of overload if the student's GPA is at least 3.300. However, a student will pay additional fee for each credit hour over 18 hours in a term. The BOK compliant tract requires two quarters with course overloads.

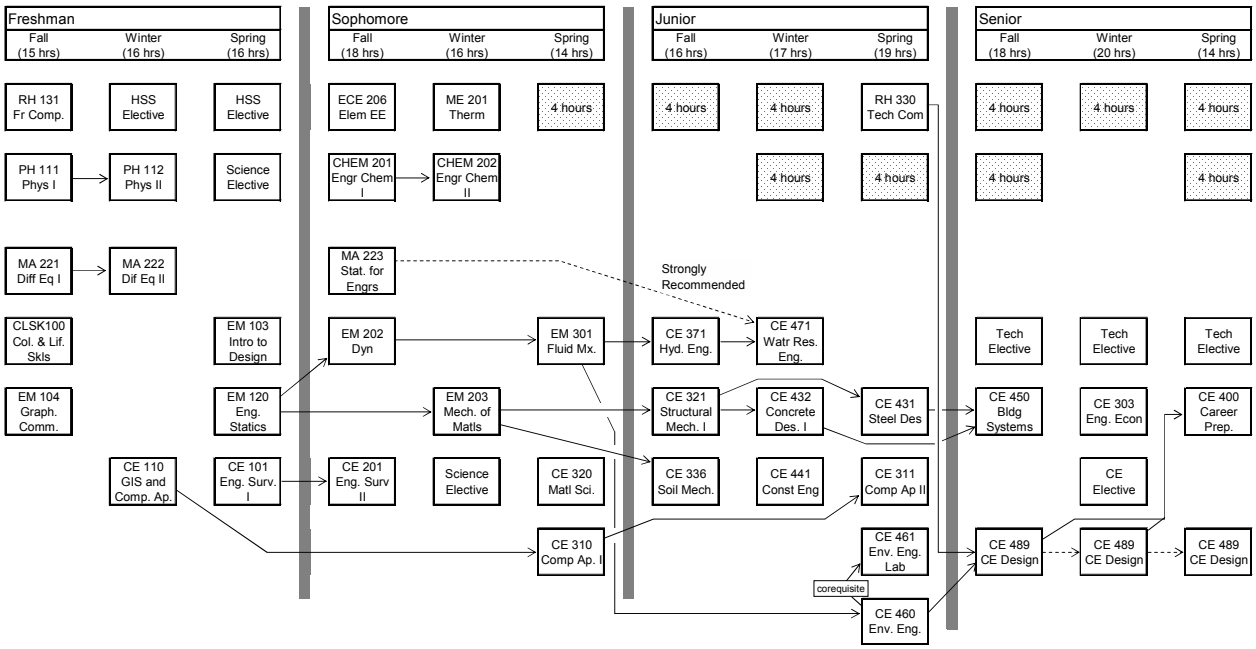

Figure 2 Course flowchart for BOK compliant tract. Courses meeting the specialization outcome are shown as shaded.

Action	Justification
MA 221 and MA 221 moved to freshman year.	Credit for MA111 – MA113 earned through Fast-Track Calculus program
HSS elective added to freshman year.	Additional hours available in quarter.
ECE206 and ME201 moved to sophomore year with no option to take CHE201 and CHE202.	ECE206 and ME201 have no prerequisites and could be moved to sophomore year. CHE201 has a CHEM201 prerequisite and could not be moved.
MA223 moved to sophomore year.	Additional hours available and multi-quarter course offering.
Science elective moved to sophomore year.	Additional hours available in quarter.

Table 2. Process followed to create BOK compliant tract within current curriculum.

Alternate configurations of the course flowchart for the BOK compliant tract are possible depending on the off-curriculum hours earned by a student. For example, students with credit for Physics 111, Physics 112, Chemistry 201 and Chemistry 202 but not the calculus sequence would require an alternate version of Figure 2. However, the calculus sequence was selected for

development of the tract because of the availability of the Fast-Tract Calculus program and the key role the calculus sequence has as course prerequisites for upper-level courses.

Finding Specialization Courses for the BOK Compliant Tract

Our next step was to identify existing courses at Rose-Hulman to meet the specialization outcome in the BOK compliant tract. The selected courses need to fulfill the intent of the specialization outcome and be either graduate-level or upper-level undergraduate courses. Additional commentary on the specialization outcome is provided in the BOK: "Examples of specialized technical areas include environmental engineering, structural engineering, construction engineering and management, public works management, transportation engineering and water resources management. Civil engineering specializations in non-traditional, boundary, or emerging fields such as ecological engineering and nano-technology are encouraged.[1]" The courses we select should prepare the student to practice in a specialized area of civil engineering.

Two existing graduate programs at Rose-Hulman, the M.S. Environmental Engineering program and the M.S. Engineering Management program, offer courses that could meet the requirements of the specialization outcome. The M.S. Environmental Engineering is offered through the Civil Engineering Department, the only graduate program offered by the department, while the M.S. Engineering Management is offered through the Engineering Management Program. The area of specialization for the BOK compliant tract would focus on environmental engineering and engineering management. The Civil Engineering Department offers six graduate-level courses in environmental engineering, Table 3, with several additional courses available through other departments. The Engineering Management program offers both an undergraduate and a graduate entrepreneurship minor that requires five courses, Table 4. The entrepreneurship programs are intended to provide the basic tools to make new technology commercially successful. The tract would consist of six or seven environmental engineering courses and three or four engineering management courses.

Table 3. Available courses in the environmental engineering graduate program. Prerequisites are shown in parenthesis.

CE561 Air Pollution
CE563 Unit Operations in Environmental Engineering (CE460)
CE564 Aquatic Environmental Chemistry
CE566 Environmental Management
CE567 Applied Hydrologic Modeling (CE471)
CE568 Applied Contaminant Transport Modeling (CE460)

Alternate master's degrees in related professional practice topic areas such as public administration, engineering management, planning, and architecture combined with a B.S. degree from an ABET accredited program may meet the definition of specialization and satisfy

the formal education component of the BOK.[1] Therefore, the acceptance of management / entrepreneurship courses to fulfill the specialization outcome of the BOK is not certain. A student completing the BOK compliant tract could earn an environmental engineering minor and possibly a technical entrepreneurship minor. The BOK compliant tract is not a concurrent B.S. / M.S. program.

Table 4. Required courses for entrepreneurship minor.

Undergraduate	Graduate
VA453 The Entrepreneur	MG532 Technical Entrepreneurship
VA498 Technology Management & Forecasting or MG423 Intro to Marketing for Technical Products	MG526 Technical Management and Forecasting or MG5XX Marketing New Technology
SL350 Managerial Accounting	MG520 Accounting for Technical Managers or MG 5XX Entrepreneurial Finance
MG427 Project Management	MG527 Project Management
VA454 Financial Economics	MG 5XX Implementing Innovation

Graduate environmental engineering courses are taken by undergraduate students to earn the environmental engineering minor. Students will take three of the courses in Table 3 as either technical or civil engineering electives to complete the requirements of the minor. For those students this reduces the environmental engineering graduate courses available for the BOK tract from six to three. Graduate or upper-level undergraduate courses offered by the Chemical Engineering Department and the Chemistry Department were considered as possible courses for the tract. However, some of these courses have prerequisites normally not taken by civil engineering students. Either the prerequisites are waived or the student must take the prerequisite course adding additional courses into their curriculum. This later proved to be a significant hurdle to overcome in scheduling courses in the tract. Course prerequisites for the environmental engineering courses are taken as required courses in the current curriculum.

Courses Scheduling

Given sufficient courses to fill the ten additional courses required in the BOK compliant tract the next task was to schedule the courses into the curriculum. Our concern was that the many of courses would have to be taken in the senior year producing course overloads. With many courses at Rose-Hulman offered once per year, it was difficult to schedule courses into the available open courses in the BOK tract. Course overload situations were often created when two or more courses were offered only in the same quarter. The BOK compliant tract is limited to one or two additional courses per quarter. This is a significant limitation on the ability to develop the tract. Successive iterations through the scheduling process produced course or prerequisite

conflicts. Based on our current course offerings and the environmental engineering minor, developing a feasible course schedule was not possible. Alternate methods to increase scheduling flexibility were considered.

Distance education courses appeared to provide the flexibility needed to eliminate the difficulties encountered in course sequencing. In addition, because distance education courses are not used to meet the course requirements of the civil engineering program, the quality of the undergraduate program will be maintained. Many engineering programs are now offering graduate courses through distance education with some programs allowing students to take courses on a non-degree seeking status. For example, both North Carolina State University and Kansas State University offer civil engineering graduate courses on a non-degree seeking status. However, all the distance education programs reviewed, including North Carolina State University and Kansas State University, require students to have a B.S. engineering degree to take courses. It appears that the idea of an undergraduate engineering student taking distance education courses at another school has not been considered in the development of distance education in the engineering field. Therefore, distance education does not offer an immediate solution to the course scheduling problem. In addition, distance education would add an additional financial burden to the student.

Independent study offers another solution to the scheduling conflicts. Although we have not developed academic requirements for the BOK compliant track we expect the tract would interest the more academically prepared students. The educational quality of an independent study depends on both the student and the supervising faculty. We believe students desiring to pursue the BOK compliant tract can effectively use independent study. Independent study, however, places an additional teaching load on the faculty member supervising the independent study.

Case Study

The courses taken by a recent graduate of the civil engineering program who earned a large number of off-curriculum hours was reviewed to determine how the student utilized the free space in the curriculum. The student transferred 51 off-curriculum hours into the program and graduated with 233 credit hours, Table 5. In four years, the student earned a B.S. civil engineering degree and area minors in German and mathematics. The student's courses were compared to the BOK compliant tract flowchart, Figure 3, to identify where additional courses not required for the civil engineering degree were taken.

The two flowcharts, Figure 2 and Figure 3, are quite similar with five courses occurring in the senior year. Four courses were taken in the sophomore and junior year. Since many science and HSS elective courses have minimal prerequisites they are easier to schedule in the sophomore and junior year. The BOK compliant tract requires a student to earn 35 off-curriculum hours (8 courses) while the student earned 51 off-curriculum hours (12 courses). This allowed the student to have six quarters with 14 or less credit hours despite earning two area minors. This confirmed our initial thoughts regarding the use of off-curriculum hours. While area minors are valuable

educational opportunities achieving the specialization outcome of the BOK may be more beneficial to a student.

Table 5. Breakdown of off-curriculum hours transferred into the degree program.

Content Area	Number of Courses	Credit Hours	Mechanism
Humanities and Social Sciences	5	20	Credit by Exam
Humanities and Social Sciences	1	4	Transfer
Mathematics	3	15	Fast Track Calculus
Science	1	4	Credit by Exam
Civil Engineering	2	8	Transfer
Total	12	51	

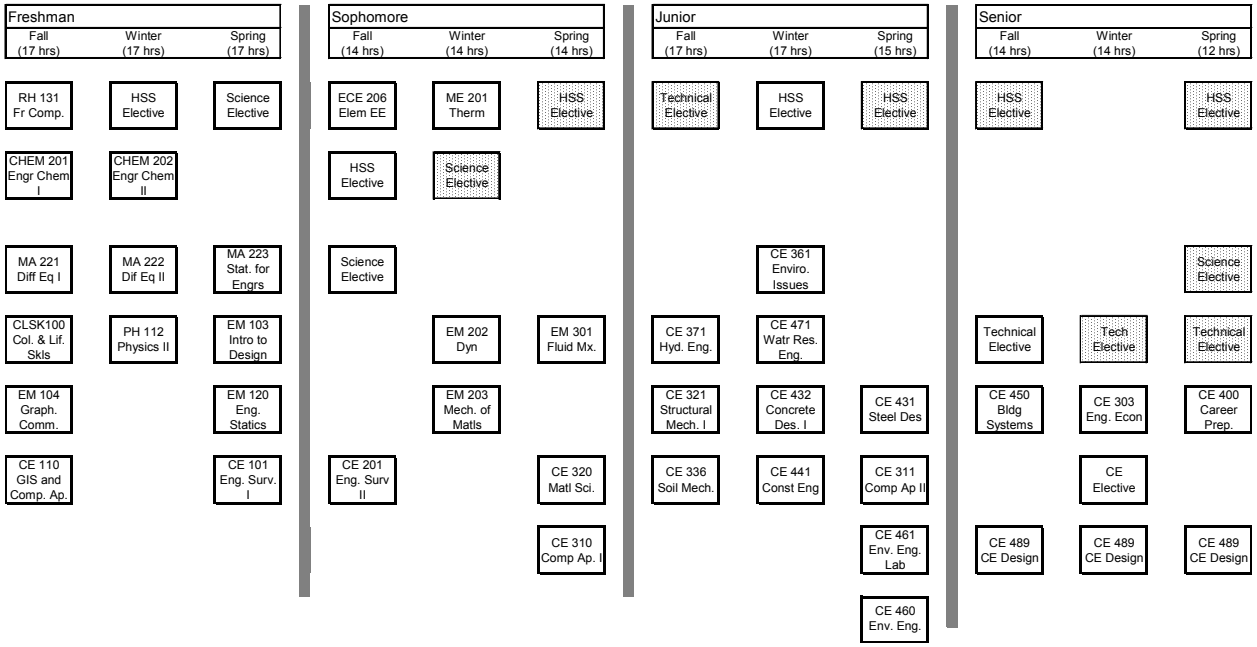

Figure 3. Curriculum flowchart for case study. Shaded boxes are additional courses not required for B.S. Civil Engineering degree.

Lessons Learned

The Civil Engineering Department at Rose-Hulman has previously concluded that modifying our curriculum to meet the complete formal education component of the BOK was not in the best interest of either the department or our students and that outcome 12 of the BOK would be attained in a post-baccalaureate program.[2] However, there are civil engineering students at

Rose-Hulman that could benefit from a program tract that provides the opportunity for them to earn a BOK compliant degree in the four years they are at Rose-Hulman. At present, only two to three students per year are expected to have sufficient off-curriculum hours (35 hours / 8 courses) to utilize the BOK tract. In addition, since the BOK tract emphasizes environmental engineering students interested in other areas of civil engineering are less likely to follow the BOK tract. The emphasis of the BOK tract on environmental engineering and engineering management was selected strictly on course availability. Because undergraduate focused civil engineering programs have no or limited graduate-level courses areas of specialization may be limited. Programs wishing to develop a BOK tract may have to rely on programs outside of traditional civil engineering such as public administration, engineering management, and planning for additional specialization courses.

Although sufficient courses were available to meet the specialization outcome of the BOK, scheduling courses into the junior and senior year posed a significant challenge. Course prerequisites often require upper-level and graduate courses be taken in the senior year. A workable sequence of courses for the BOK compliant tract could not be developed using graduate environmental engineering courses and engineering management courses. The use of distance education to ease the scheduling problem does not appear to be feasible at this time. The use of independent study to ease the scheduling problem is possible but would increase the teaching load on the supervising faculty. In developing a BOK tract programs need to evaluate how the senior year is impacted and if sufficient courses can be moved from the senior year to allow the student to take the majority of the specialization courses in their senior year.

As the BOK becomes an accepted standard for education and licensure, civil engineering programs may decide to meet the BOK through a dual B.S. / M.S. degree program. Several engineering programs currently offer some form of a five-year dual B.S. / M.S. degrees including Drexel University, University of Colorado at Boulder, Old Dominion University, and Bucknell University. However, undergraduate focused engineering programs may either not be able or desire to offer such a program. A BOK tract may provide these programs a mechanism to offer a BOK compliant degree to a few of their students.

There will be the need for an accreditation process to recognize a student completing the entire formal education component of the BOK within a four-year B.S. degree program. Until an accreditation process is established, it may be difficult to convince students to complete a BOK compliant tract. Fortunately, there is little downside to students completing the tract. Unless they graduate in three years the students will have available time in their curriculum to take the additional courses needed to satisfy the specialization outcome.

Another option for undergraduate focused engineering programs is to focus on enhancing professional breadth (outcomes 13, 14, and 15) rather than specialization. We need to discuss the role of non-engineering related area minors in engineering education. Faculty at Rose-Hulman recognize the value of HHS courses in strengthening the technical education of the civil engineering student. However, we should discuss how HSS courses can be better used to enhance the professional breadth outcomes.

Bibliography

1. ASCE. Civil Engineering Body of Knowledge for the 21st Century. January 12, 2004.
2. Robinson, M. and K. Sutterer. The ASCE BOK – A Case Study of the Evaluation and Design of a BOK Curriculum. 2004 ASEE Salt Lake City, Utah.
3. Academic Prerequisites for Licensure and Professional Practice, ASCE Policy Statement 465.

Biographical Information

MICHAEL ROBINSON is an Environmental Engineer and Assistant Professor of Civil and Environmental Engineering at Rose-Hulman Institute of Technology.

KEVIN SUTTERER is a Geotechnical Engineer and Associate Professor of Civil Engineering at Rose-Hulman Institute of Technology.